# Network Telemetry System Performance Tests in Support of the Mark III Data System Implementation

R. D. Rey and E. J. Nipper
Network Operations Section

*This article presents a description of Network Telemetry System Performance Tests that were executed throughout the DSN in support of the Mark III Data System Implementation.*

## I. Introduction

System Performance Tests (SPTs) are executed throughout the DSN whenever a modification is made to the Network Telemetry System that affects its performance. This is the case when new software or hardware is added. For the Mark III Data System Implementation both new hardware and new software were added to the Telemetry System. The purpose of this article is to describe the effort that was undertaken in executing telemetry SPTs throughout the DSN after the implementation of the Mark III Data System.

The philosophy and the objectives of the SPTs will be discussed to demonstrate the benefits gained by performing these tests. The telemetry SPTs will be described along with the test procedure and test software. Finally, a summary of the results and the status of the Network Telemetry System will be presented.

## II. Objectives of System Performance Testing

The development of test procedures, test software and the execution of the telemetry SPTs are performed to accomplish certain objectives. The overall objective is to verify that the Network Telemetry System meets specified operational capabilities. These capabilities are defined in Refs. 1 through 3. The SPT must verify that the telemetry system configuration and interface requirements are satisfied and must also evaluate that the Telemetry System meets specified performance criteria.

The telemetry SPT is designed so that it can be used to locate or diagnose system problems. The problems may occur during the installation of new equipment or software, or they may be the result of system failures uncovered during DSN operations.

Use of SPTs for Pre-Pass Preparation Tests (PPTs) required that the SPT procedures be modular. The modularity feature of the procedure enhances the capability to test modifications that may affect the capabilities of the Telemetry System.

An additional objective of SPTs is to provide some system level training of station personnel. The SPTs are prepared so that the configurations used are as near as possible to configurations used during spacecraft tracking operations. Thus, by using the test procedures station personnel can gain experience in operating the Telemetry System.

## III. Test Configuration

Figure 1 shows the general telemetry test configuration for both a 64-meter and 26-meter station. Also shown in Fig. 2 are the 26-meter conjoint differences. Simulated data are generated in the Simulation Conversion Assembly (SCA). The simulated data called for in the tests are a pseudo-noise (PN) sequence at the required bit rate. The SCA modulates these data with a square wave subcarrier, which is set at a specific modulation index by using a wave analyzer at the Receiver (RCV). The data on the subcarrier phase modulate a carrier generated in the test transmitter, which is interfaced to the RCV through ambient load, and the test transmitter signal level is adjusted to obtain the required signal-to-noise ratio (SNR). The SNR is accurately measured at the Y-factor detector.

The telemetry data handling software (DSN Program Library Software No. DMT-5085-OP) resides in the Telemetry Processor Assembly (TPA), which is a general purpose minicomputer. The TPA software can be configured to process data using either of two telemetry channels. Acceptable data rates and coding schemes are as follows:

(1) Channel 1 (CH1) short constraint length convolutionally coded data, with data rates from 10 to 115.2K bits per second (BPS), are decoded in the Maximum Likelihood Convolutional Decoder (MCD) before being passed to the TPA for formatting. Long constraint length convolutionally coded data up to and including 4096 BPS are software sequentially decoded and formatted by the TPA. Block coded data (CH1) up to 2.0K are passed directly from the SSA to the TPA for software decoding and formatting. Uncoded data from the SSA are sent directly to the TPA for formatting.

(2) Channel 2 (CH2) block coded data in CH2 are decoded in the Block Decoder Assembly (BDA) at rates up to and including 16.0K BPS and sent to the TPA for formatting. Long constraint length convolutionally coded data (CH2) up to and including 4096 BPS are software sequentially decoded in the TPA and formatted for output. Uncoded data from the SSA are sent directly to the TPA for formatting.

*High-Speed Data*

The TPA formats the data into a High-Speed Data (HSD) block, which it then encloses in the data portion of a Sub-System Block (SSB) for routing through the Star Switch Controller (SSC) to the Communications Monitor and Formatter (CMF). The CMF then strips off the SSB to leave an HSD block. The HSD block is simultaneously transmitted to the GCF and recorded on a digital ODR at the CMF.

*Wide-Band Data*

The TPA, in order to accommodate data rates greater than 7.2K from the BDA and MCD, has the capability of formatting and outputting Wide-Band Data (WBD) to the GCF. These data can also be recorded on a High Rate Operational Data Record (HODR) at the TPA.

The transmitted data blocks are described in detail in Ref. 4. The specifications placed on the telemetry system by these requirements are rigorously tested and adhered to.

Interface information in the form of SSBs is transmitted from the TPA through the Star Switch Controller (SSC) to the Digital Instrumentation Subsystem (DIS). The SSBs are shipped via HSD blocks and validated at the System Performance Test Assembly (SPTA). The validation consists of checking subsystem status and alarms.

The SPTA is used to process the data for the tests using the Telemetry System Test Software, DMI-5124-TP and Performance Test Procedures, which runs on disc. HSD blocks are simultaneously transmitted to the SPTA via the CMF and are recorded on a digital ODR at the CMF. WBD blocks are simultaneously transmitted via WBD lines to the SPTA, and recorded on digital recorders at the TPA. To use the SPTA as the processing computer, the TPA HSD/WBD lines are patched at the station communications center to the SPTA HSD/WBD lines.

## IV. Telemetry System Test Software

Telemetry SPT Program DMT-5124-TP resides in the backup CMF, which will be called the SPTA. The Telemetry System Test Software and Performance Test Procedures are combined on disc with other test programs and procedures to make up System Performance Test Program DMI-5001-OS. Only DMI-5124-TP, the Telemetry Test Procedures, and the Executive Program, DMI-5122-TP, with which they interface, are described in this report.

The Executive Program interfaces with the Telemetry String to be tested through the HSD/WBD on-site Ground Communication Facility (GCF) equipment and the Star Switch Controllers (SSCs). These interfaces allow the Telemetry String and its operational software to be tested in an operational environment. In other words, the telemetry system is tested relative to the data as if they were leaving the station.

Telemetry data HSD/WBD blocks may be output on the line printer for visual inspection, although normal operation utilizes the software to output and calculate the following:

(1) Standard block header information consisting of source, destination, data-dependent type (DDT), user-dependent type (UOT), spacecraft identification, day of the year and the time of the block formation.

(2) Formatted configuration and lock status with receiver AGC or signal level in dBm, and bit SNR in dBm.

(3) TPA and channel number bit error rate (BER) or word error rate (WER), erasure rate and symbol error rate measured over a given period.

(4) Signal level for the y-factor calculation computed by the software relative to the input parameters.

In the bit error rate test, the data may be either hardware PN, software PN or fixed pattern. The test software synchronizes to the data and does a bit-by-bit comparison. The WER/BER accumulation may be over any chosen interval resulting in a grand total output, while statistics can be displayed as interim summaries at intervals as required. Also grand totals will be output immediately if test is terminated early.

As the test is being executed, the test software will detect errors and display error messages as follows:

(1) The $\Delta t$ between telemetry HSD/WBD blocks not within specified tolerances.

(2) Incorrect data type, as evidenced by the inability to achieve synchronization.

(3) Binary time and millisecond clock differences.

(4) BSN errors.

(5) GCF errors.

(6) Message buffer overflow (inability to output error messages because of buffer overflow).

An additional capability of the SPT software is the real-time dumping of High Speed Data during operations. Both incoming and outgoing real-time data can be dumped to a line printer in either Hex, octal or english formats. This allows station personnel to perform diagnostics of system problems during tracking operations.

## V. Test Procedure Format

Performance Test Procedures are combined on disc with other test programs and procedures to make up System Performance Test Program DMI-5001-OS (Refs. 5 and 6). The procedures on Disc are handled by the TLM and EXEC Test Programs in the same manner as operator inputs from any other I/O device. A list of these directives, normally referred to as Operator Control Inputs (OCIs), is contained in the Software Operators Manual (SOM) which accompanies the programs.

The programs will operate in any of the station MDS computers; however, because of interface requirements for testing, such as HSD/WBD, printer/plotter, etc., the procedures were designed for operating only in a Communications Monitor and Formatter Assembly (CMFA), which, when operating as the test computer, is the aforementioned System Performance Test Assembly (SPTA).

The overall test is divided into three main tests. Each test contains a number of subtests that are modular so that any test can be run independently. This allows the procedures to be used for pretrack readiness tests (PRTs), trouble-shooting and new equipment or software tests. It also allows for reduced testing when resources so demand.

The three tests are the Configuration and Interface Tests, the Telemetry Performance Tests and the Operational Data Record (ODR) Test. These tests all call out a Test Preparation procedure as needed.

### A. Configuration and Interface Tests

Configuration and Interface Tests are performed on the two telemetry channels. They test the telemetry operational software and hardware interfaces using all operational configurations planned for project support. These tests also check HSD and WBD interfaces and HSD/WBD block configurations. The blocks are verified by inspection of the formatted block headers, and configuration and lock indicators are formatted by the test software for ease of interpretation. Monitor messages verifying that the initialization, status and calculation messages are correct is also accomplished in these tests.

Although the AGC/dBm conversion test and the signal-to-noise ratio (SNR) calculation test are separate sections of the test procedure, they are normally run with the configuration and interface tests. The AGC/dBm conversion test verifies that software can perform a correct conversion from AGC volts to signal level in dBm. The conversion parameters are entered in the program, and accuracy of the conversion is checked to see that it is within ±0.05 dBm. The SNR calculation test verifies the accuracy of the software SNR estimator routine. SNRs of varied dB are set up using the y-factor machine. The calculation is verified to be accurate within ±0.3 dB.

The important aspect of the configuration and interface tests is that they insure that the functional capabilities of the Telemetry System exist.

### B. Telemetry Performance Test

The Telemetry Performance Tests determine the capability of the Telemetry System to meet the DSN support performance requirements. These tests are designed to evaluate telemetry performance at threshold SNRs with CH1 and CH2 configured in Project support modes.

The test measures the output data Word Error Rate (WER) for coded data and the Bit Error Rate (BER) for uncoded data given an input data signal-to-noise ratio. The results are compared against predicted BER/WER, and if they are within given tolerances, the performance is considered to be acceptable. The predictions are based on available mathematical models of the Telemetry System (Refs. 7 through 9). These models are evaluated using a computer program. This program is called the Telemetry Analysis Program, and is used primarily to generate performance parameters for the telemetry SPTs.

A strong signal test is always executed prior to a weak signal test. The strong signal test is run to detect gross errors in the HSD/WBD blocks that would invalidate the weak signal tests, which take much longer to perform. The strong signal test also confirms the set up configuration and interfaces.

The weak signal performance tests are run for all operational configurations and data rates. An accurate SNR is set using the Y-factor machine, and the WER/BER is measured and recorded. The SNR calculation is also checked for accuracy.

### C. Original Data Record (ODR) Tests

Communications Monitor and Formatter (CMF) ODRs, TPA temporary ODRs (TODRs) and High Rate ODRs (HODRs) are verified in the following way. An ODR or HODR is generated, and a short bit error test (BER) is run to insure the quality of the data. Also TODR operational capability is exercised to ensure the ODR or HODR will contain TODR despooled data. The ODR or HODR is then played back, and a BER test is conducted to verify data content and quality.

Analog tapes are generated at a specific SNR and then played back. The tape output SNR is obtained and compared against the set SNR. The tape output SNR must be no greater than 1 dB, less than the set SNR.

Data reporting is accomplished by using data sheets which are automatically output by the test procedure. These are presented in Fig. 3.

Test results are analyzed and recorded by the telemetry System Cognizant Operations Engineer (SCOE).

## VI. Mark III Data System Implementation Network Telemetry Test Status and Results

Execution of network telemetry SPTs for the Mark III Data System Implementation began November 1976 with a completion date of March 22, 1978. The tests were carried out at the following stations:

(1) Goldstone, California: DSS 11, DSS 12, and DSS 14.

(2) Tidbinbilla and Honeysuckle: DSS 42, DSS 43, DSS 44.

(3) Madrid and Cebreros, Spain: DSS 62, DSS 63, DSS 61.

Station personnel, while conducting the SPTs, uncovered problems and gained working experience and knowledge about the system. Upon completion of the SPTs, station personnel sent the results to the telemetry SCOE. The data were recorded and analyzed to evaluate the status of the Telemetry System.

## VII. Summary

All Telemetry SPTs for the Mark III Data System have been completed throughout the DSN, and the performance as demonstrated by the Telemetry SPTs has been acceptable.

Also, SPTs were designed for continued use as System Maintenance and Operations Tests, which can be used to maintain station performance and diagnosis system problems during both tracking operations and maintenance periods. Furthermore, the SPTs can be used for station readiness tests and, with some modification, can be used to provide a computer-aided countdown capability.

# References


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5. *DSIF Standard Test Procedure Telemetry System Performance Test.* Document No. 853-96; 2A-22. Jet Propulsion Laboratory, Pasadena, Calif., Jan. 16, 1978 (JPL internal document).

6. *DSN System Requirements Detailed Subsystem Interface Design,* Document No. 820-14. Jet Propulsion Laboratory, Pasadena, Calif., Feb. 1, 1978 (JPL internal document).

7. *Deep Space Network/Flight Project Interface Design Handbook,* Document No. 810-5 (Rev. D) (JPL internal document).

8. Edelson, R. E., *Telecommunications Systems Design Techniques Handbook,* Technical Memorandum 33-571. Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1972.

9. Tausworthe, R. C., "Communications Systems Development: Efficiency of Noisy Reference Detection," in *The Deep Space Network*, Space Programs Summary 37-54, Vol. III, pp. 195-201. Jet Propulsion Laboratory, Pasadena, Calif., Dec. 31, 1968.

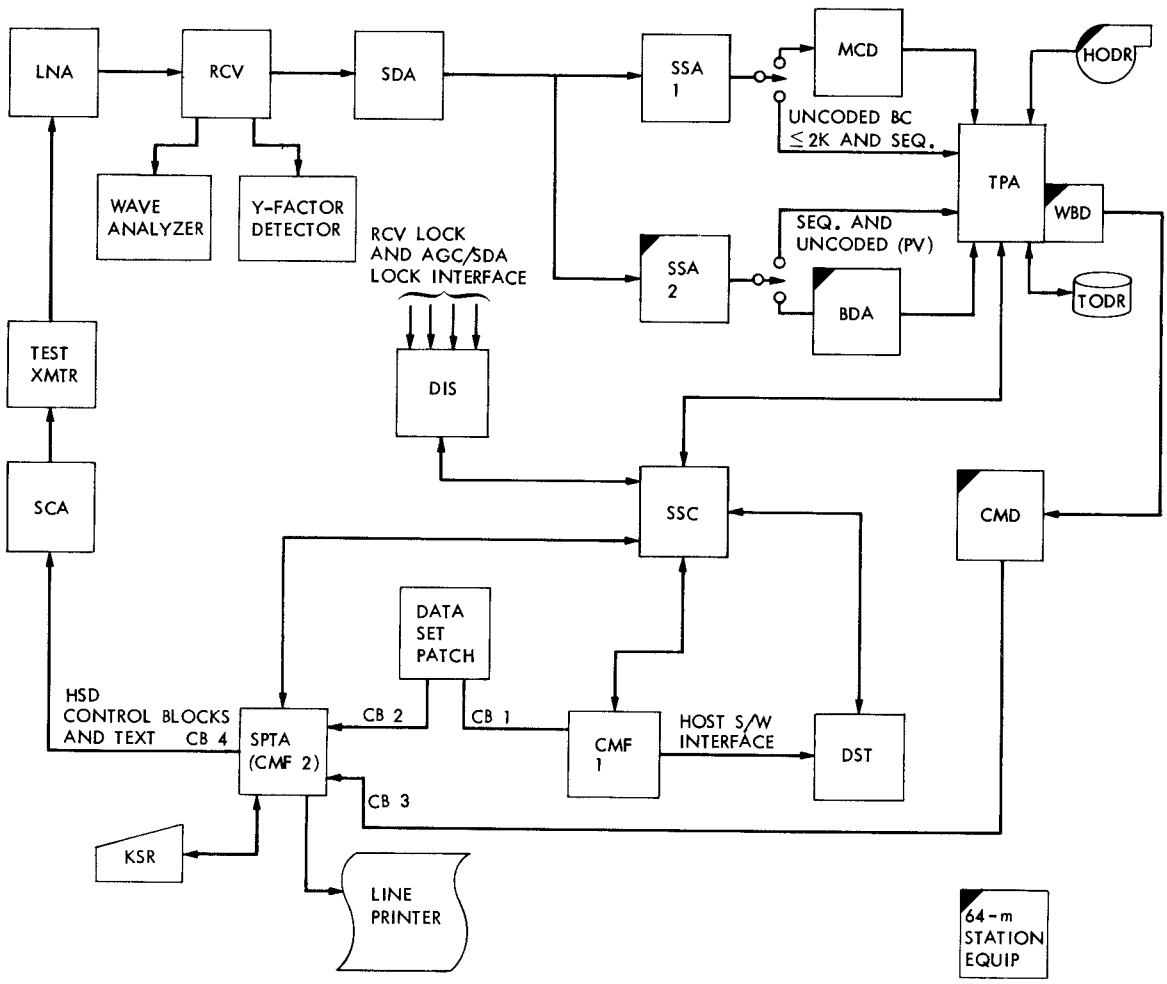



**Fig. 1. 26/64-m telemetry SPT diagram (typical)**

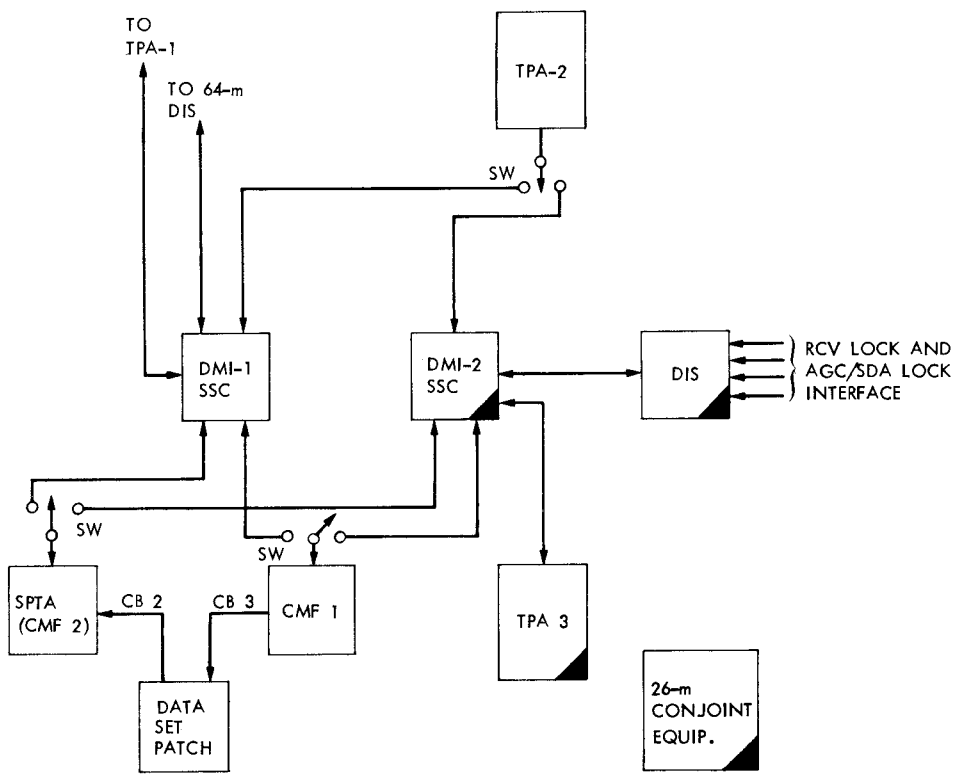
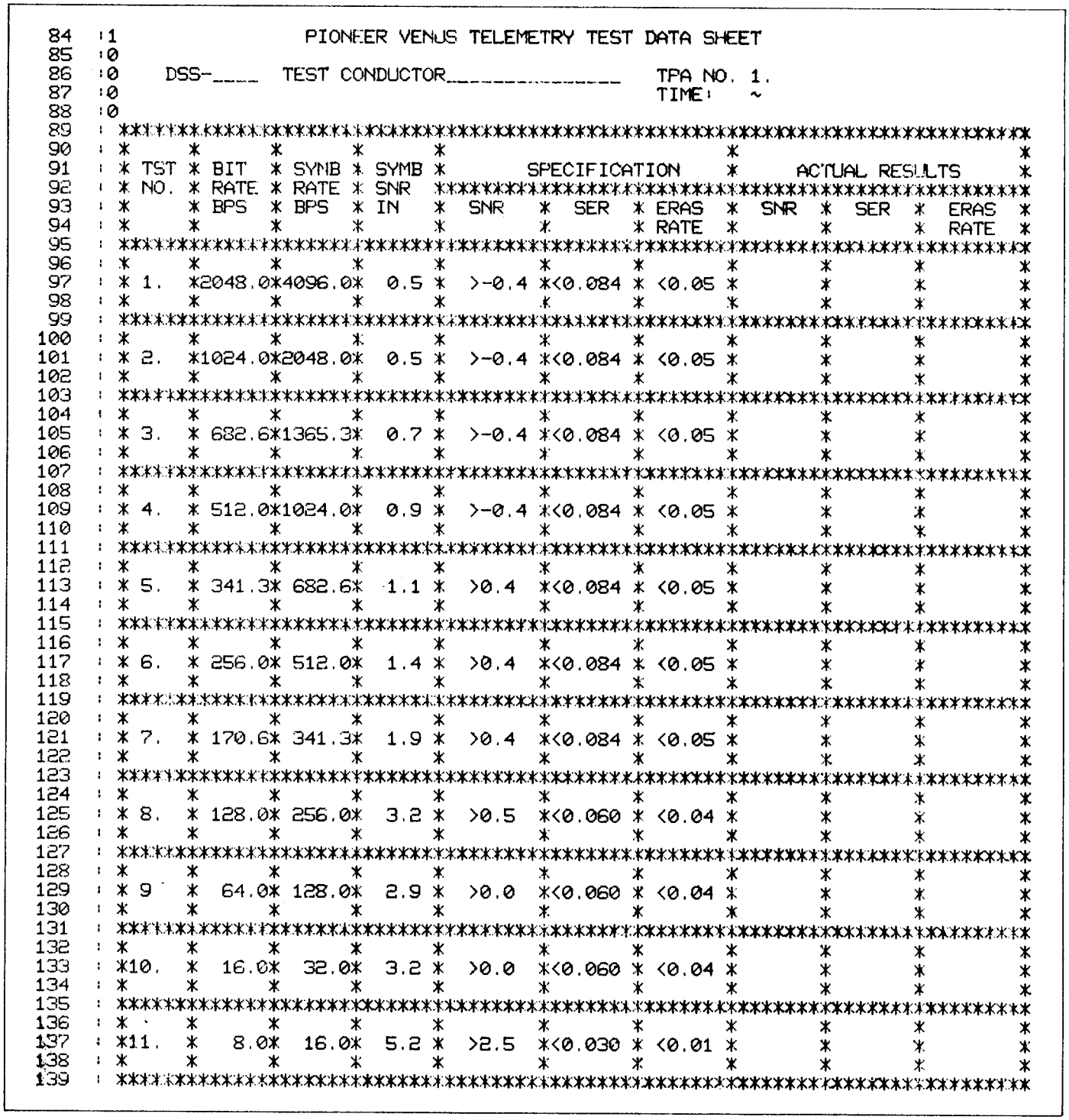



**Fig. 2. 26-m conjoint interface differences**



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1                  PIONEER VENUS TELEMETRY TEST DATA SHEET
0
0    DSS-____  TEST CONDUCTOR_____________   TPA NO. 1.
0                                            TIME:  ~
0
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| TST NO. | BIT RATE BPS | SYMB RATE BPS | SYMB SNR IN | SPECIFICATION SNR | SPECIFICATION SER | SPECIFICATION ERAS RATE | ACTUAL RESULTS SNR | ACTUAL RESULTS SER | ACTUAL RESULTS ERAS RATE |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 2048.0 | 4096.0 | 0.5 | >-0.4 | <0.084 | <0.05 | | | |
| 2. | 1024.0 | 2048.0 | 0.5 | >-0.4 | <0.084 | <0.05 | | | |
| 3. | 682.6 | 1365.3 | 0.7 | >-0.4 | <0.084 | <0.05 | | | |
| 4. | 512.0 | 1024.0 | 0.9 | >-0.4 | <0.084 | <0.05 | | | |
| 5. | 341.3 | 682.6 | 1.1 | >0.4 | <0.084 | <0.05 | | | |
| 6. | 256.0 | 512.0 | 1.4 | >0.4 | <0.084 | <0.05 | | | |
| 7. | 170.6 | 341.3 | 1.9 | >0.4 | <0.084 | <0.05 | | | |
| 8. | 128.0 | 256.0 | 3.2 | >0.5 | <0.060 | <0.04 | | | |
| 9 | 64.0 | 128.0 | 2.9 | >0.0 | <0.060 | <0.04 | | | |
| 10. | 16.0 | 32.0 | 3.2 | >0.0 | <0.060 | <0.04 | | | |
| 11. | 8.0 | 16.0 | 5.2 | >2.5 | <0.030 | <0.01 | | | |

**Fig. 3. Data Sheet 1 — performance test data sheet (typical)**